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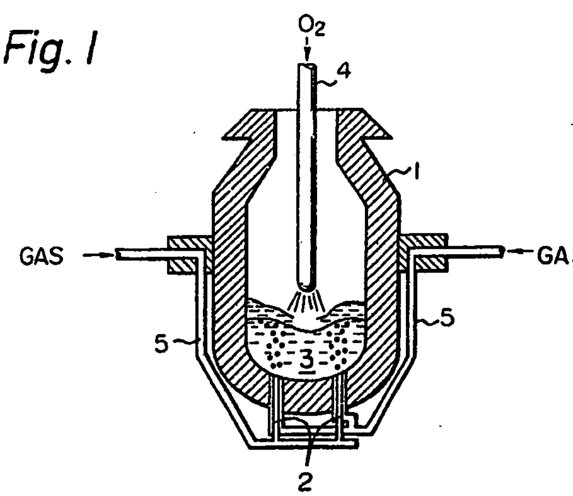
(54) Simultaneous top- and bottom-blowing in oxygen steelmaking

(57) In a method of steelmaking in a basic oxygen furnace, a bottom-blowing gas predominantly comprising carbon dioxide is introduced into a molten metal through at least one nozzle provided in the bottom or side wall of a furnace at least partly during the period of time from the beginning of top blowing with oxygen to the tapping of the melt, and the flow rate of the bottom-blowing gas is 1/200—9/100 the rate of oxygen impinged upon the melt through a lance. The bottom-blowing gas is preferably composed of flue gas which has been passed through a dust collector and burner.

Fig. I



GB 2 054 655 A

Fig. 1

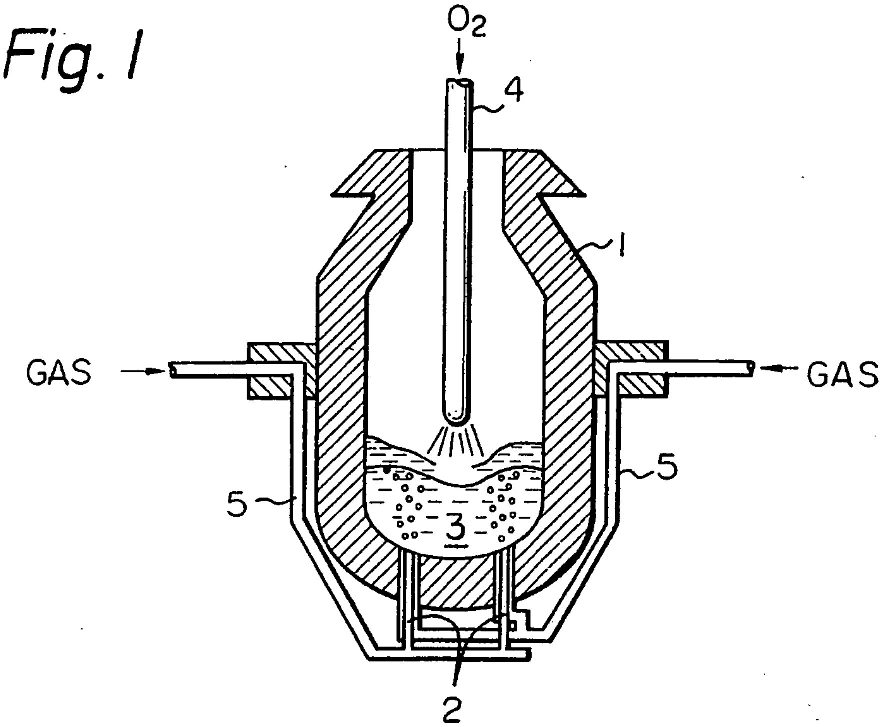

O2
4
1
GAS
GAS
5
5
3
2

Fig. 2

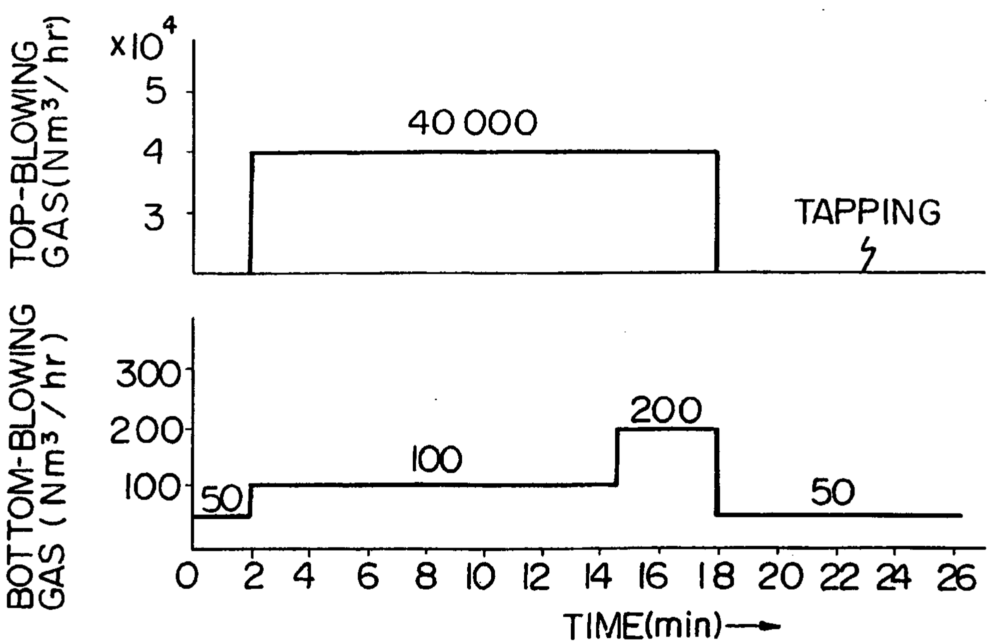

TOP-BLOWING GAS(Nm³/hr)
x10⁴
5
4
3
40 000
TAPPING
BOTTOM-BLOWING GAS (Nm³/hr)
300
200
100
50
100
200
50
0 2 4 6 8 10 12 14 16 18 20 22 24 26
TIME(min)

Fig. 3

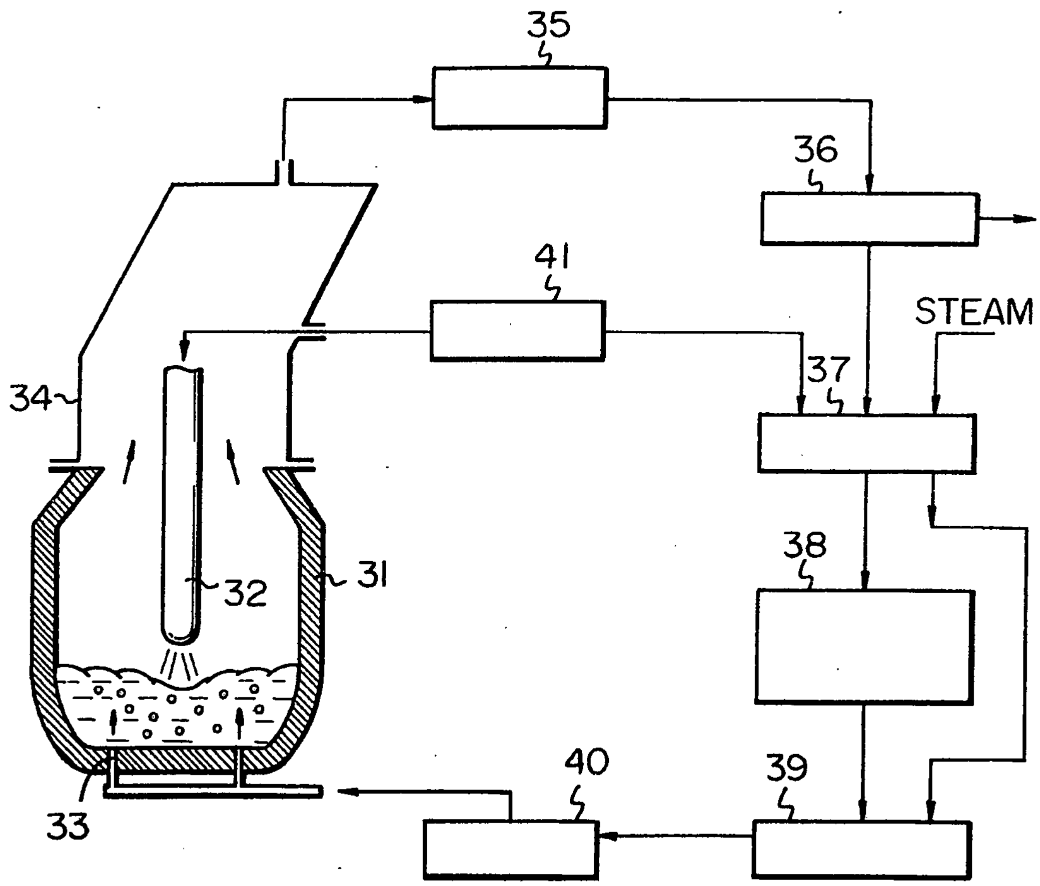


Fig. 4

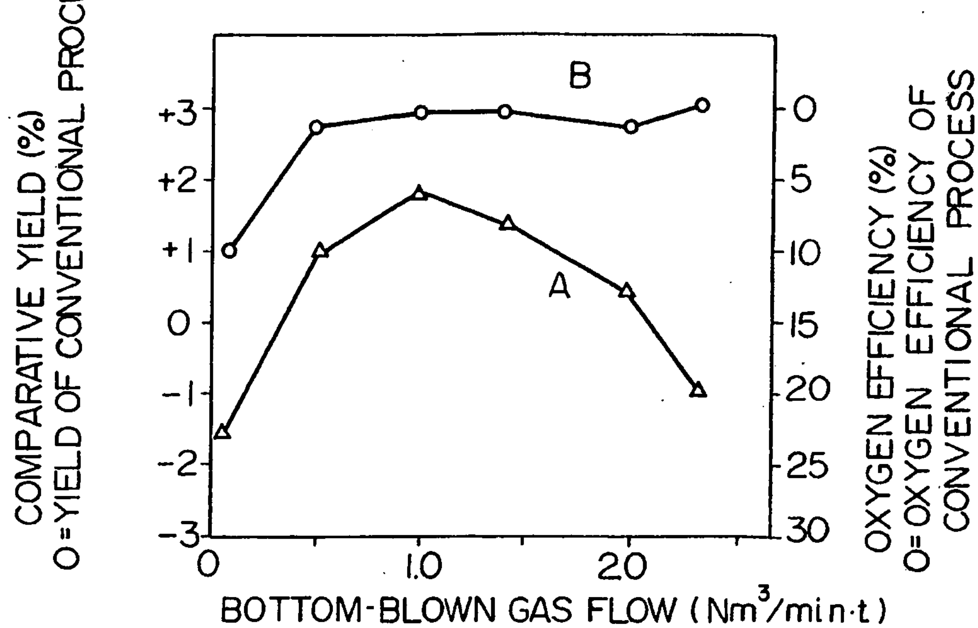

COMPARATIVE YIELD (%)
O=YIELD OF CONVENTIONAL PROCESS
OXYGEN EFFICIENCY (%)
O=OXYGEN EFFICIENCY OF CONVENTIONAL PROCESS
B
A
+3
+2
+1
0
-1
-2
-3
0
5
10
15
20
25
30
0
1.0
2.0
BOTTOM-BLOWN GAS FLOW (Nm³/min·t)

Fig. 5

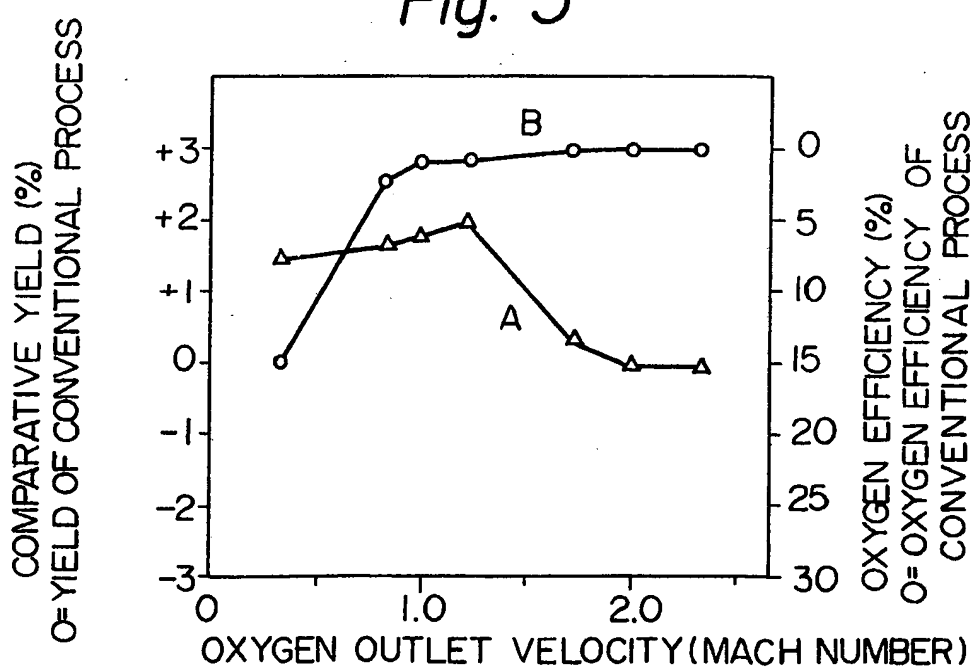

COMPARATIVE YIELD (%)
O=YIELD OF CONVENTIONAL PROCESS
OXYGEN EFFICIENCY (%)
O=OXYGEN EFFICIENCY OF CONVENTIONAL PROCESS
B
A
+3
+2
+1
0
-1
-2
-3
0
5
10
15
20
25
30
0
1.0
2.0
OXYGEN OUTLET VELOCITY (MACH NUMBER)

Fig. 6

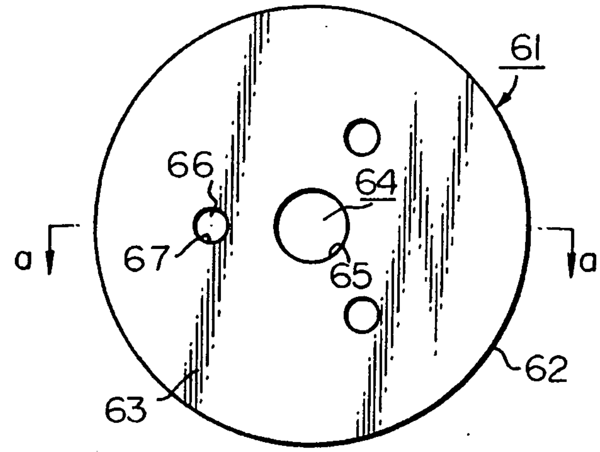
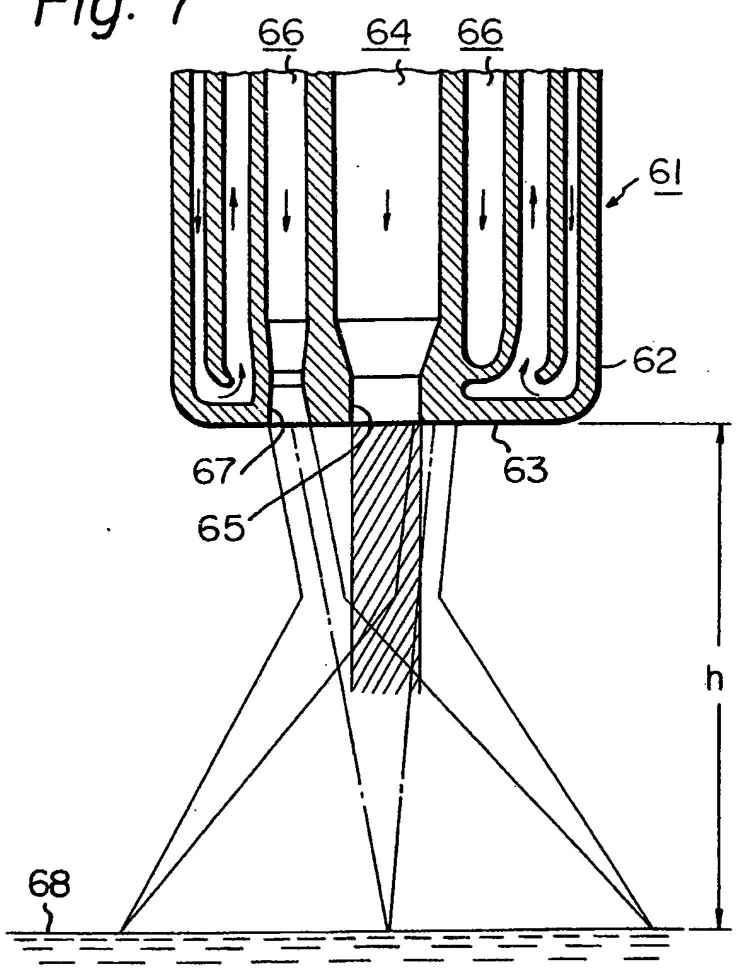


Fig. 7



SPECIFICATION

Production of carbon steel and low-alloy steel with bottom blowing basic oxygen furnace

This invention relates to the production of carbon steels and low-alloy steels with a bottom blowing basic oxygen furnace (hereinafter sometimes referred to as "bottom blowing BOF"). More particularly, this invention relates to a steel making process in which a blow of gas is injected into a melt so as to promote the agitation of the melt during top-blowing of pure oxygen through a lance.

In the oxygen top-blowing steel making process, molten iron, scrap and other starting materials are charged into a converter and then refining of steel is carried out while blowing pure oxygen onto the charge melt through an oxygen lance. In the early or intermediate stage of the blowing, the oxygen vigorously reacts to the melt still containing a substantial level of carbon so that the generation of carbon monoxide is sufficient to bring about thorough agitation of the melt.

However, since the amount of carbon in the melt decreases at the end stage of the blowing, the generation of carbon monoxide rapidly diminishes and the reaction between the molten steel and slag rapidly goes down. Due to such decrease in decarburizing efficiency of oxygen, i.e. decrease in the proportion of oxygen which has been used to effect decarburization to the total amount of oxygen blown into the melt, the presence of excess oxygen is unavoidable resulting in oxidation of iron far beyond the equilibrium level. In addition, due to insufficient agitation of the molten steel and slag, there will be a temperature difference between them, resulting in a dephosphorizing reaction proceeding in an adverse direction. This is caused by less agitation of the molten metal. Therefore, it has been proposed to provide an oxygen converter with an electromagnetic agitator. It has also been proposed to add scrap iron to the melt at the last stage of blowing to generate a turbulence of the melt due to a temperature difference between the scrap and melt. However, these proposals have never been practiced because they require a high construction cost and their effect is supposed not so large as expected.

Furthermore, it has been proposed to rotate or swing the oxygen blowing lance to provide additional agitation of molten metal and slag. But this promotes the agitation of slag, not of the molten steel.

In order to eliminate these prior art disadvantages, it has also been proposed to inject a blow of gas into a molten metal through the bottom while pure oxygen is blown onto the melt through a lance. Examples of the gases to be injected into the melt are limited to an inert gas such as argon and a neutral gas such as nitrogen. However, since argon is very expensive, and a relatively large amount must be blown into the melt in the bottom blowing so as to thoroughly agitate the melt, a sharp increase in cost is unavoidable. The introduction of pure nitrogen or a gas predominantly comprised of nitrogen, such as a compressed air will increase the nitrogen content of the melt. Thus, the blowing of nitrogen is not practical, either.

French Patent 1,151,053 and U.S. Patent 3,854,932 disclose the bottom blowing of various kinds of gases, including argon, steam, air, carbon oxide, etc. However, U.S. Patent 3,854,932, for example, is directed to the production of stainless steel, so that the main purpose is to suppress the oxidation of chromium. Thus, it is necessary to carry out the process of this invention under subatmospheric conditions. In addition, it treats these gases as being equivalent. Furthermore, since the French patent teaches the bottom blowing of a relatively large amount of gas into the melt, the process disclosed therein is less economical.

In addition, the oxygen is blown through the conventional lance into the steel melt as a supersonic oxygen jet. Therefore, the temperature at the impinging surface between the oxygen and molten steel, goes up to 2,000°C or more. Therefore, iron loss due to evaporation (hereinafter referred to as "fume-loss") is significant. Furthermore, the problems of spitting of fine iron particles after firing and the slopping of slag and molten steel still remain unsolved. Therefore, even in this combined blowing process, a remarkable increase in tapping yield cannot be expected. This is because, according to the conventional oxygen steel process, the Lavel-type nozzle is used as a lance and the oxygen jet is injected at a supersonic rate of Mach 2—2.5 so that the disadvantages mentioned above are inevitable. In order to avoid such disadvantages controlling the decarburization rate and the slag conditions during blowing has been tried. However, it is difficult to control these factors during operation and, in fact, such improved results as expected could not be obtained.

A recent development in this field is the "Q-Bop" process, in which instead of top-blowing of pure oxygen, the oxygen is blown into the molten metal through nozzles provided at the bottom of the converter. Since the "Q-Bop" process employs the pure oxygen gas for bottom-blowing instead of for top-blowing, it is necessary to blow another gas such as propane for protecting the nozzles. Consequently, in this case, too, a relatively large amount of blowing gas must be injected into the molten metal. The "uniform mixing time" hereinafter described in detail is about 10 seconds.

The primary object of this invention is to provide a method of producing carbon steel and low-alloy steel with a basic oxygen furnace.

Another object of this invention is to provide an economical method of thoroughly agitating a melt in an oxygen steel converter.

Still another object of this invention is to provide a method of producing carbon steel and low-alloy steel with a basic oxygen furnace, in which a waste gas discharge from the furnace is circulated

and used as the only source of the gas to be blown through the bottom of the furnace.

Still another object of this invention is to provide a method of producing carbon steel and low-alloy steel with improved tapping yield.

This invention resides in a method of producing carbon steels and low-alloy steels in a basic oxygen furnace, characterized in that a blow of gas predominantly comprised of carbon dioxide is introduced into the molten metal through at least one nozzle provided in the bottom or side wall of said basic oxygen furnace at least partly during the period of time from the beginning of blowing to the tapping of the melt, the flow rate of the bottom blowing gas being 1/200—9/100 the rate of oxygen impinged upon the melt through a lance.

The blowing gas predominantly comprised of carbon dioxide may comprise more than 50% by volume of carbon dioxide, including the exhaust gas from a metal refining furnace such as a steel converter and a purified or concentrated gas derived from a combustion gas of a heating furnace. Other components of the blowing gas may be nitrogen, oxygen, etc. The more nitrogen there is in the blowing gas, the greater the nitrogen content of the melt. In case of producing the usual rimmed steels, nitrogen in an amount of less than 50% by volume may be present in the blowing gas without bringing in any troubles. But it is preferable to use a gas containing less than 20% by volume of nitrogen if it is intended to produce a low-nitrogen steel. It is to be noted, however, that if a relatively large amount of nitrogen is blown into the melt, the nitrogen will be almost completely removed until the carbon content reduces to 0.5%. This is because the denitrifying reaction takes place vigorously when the carbon content is more than 0.5%. Thus, nitrogen gas may be blown into the melt instead of carbon dioxide gas until the carbon content reduces to 0.5%. After the carbon content reduces to 0.5% or less, the bottom blowing should be carried out in accordance with this invention.

In addition, mushroom deposition about 5—15 cm thick will sometimes be formed at the tip of the nozzle in practicing the method of this invention because of the temperature difference found between the nozzle cooled with the blown gas and the melt surrounding it. It is supposed that the deposition is formed at the beginning of operation and is mainly comprised of slag. The formation of such a deposition at the tip of a nozzle makes difficult the blowing of gas in a predetermined amount. In order to avoid such a difficulty, it is advisable to increase the pressure or flow rate of the blowing gas to such a level that the deposition is made porous due to the passing of the gas through the nozzle. It is also advisable to incorporate a small amount of oxygen in the blowing gas so as to utilize its generation of heat in accordance with the equation:

$$2CO + O_2 = 2CO_2$$

According to this invention, the bottom blowing is applied at least partly during the period of time from the beginning of the blowing of oxygen through a lance to the tapping of the refined molten steel. The bottom blowing rate may be varied during the process, e.g. depending on the proceeding of the steel making reaction in the converter. For example, it is preferable to increase the blowing rate at a final stage of the top-blowing so as to compensate for the decrease in agitation due to the going down of the decarburizing reaction. Therefore, an effective reaction can be continued successfully to the end, resulting in a remarkable reduction in the amount of gas used.

The blowing of carbon dioxide is preferably carried out by way of at least one nozzle provided in the bottom or in the side wall of the oxygen steel converter.

The advantages obtained by using carbon dioxide as a blowing gas is not only that it is less expensive than an inert gas such as argon, but also that carbon dioxide increases twice in volume when it is added to the melt in accordance with the equation: $C + CO_2 = 2CO$, bringing about violent agitation of the melt. In other words, less gas is required to achieve the same effect of agitation in comparison with argon or nitrogen. This reduction in amount of gas used means that it is possible to simplify the equipment including piping required to blow gas into the molten steel in accordance with this invention. This is very advantageous from a practical viewpoint.

According to this invention the flow rate of the bottom blowing gas is limited to less than 9/100, preferably less than 5/100 the rate of oxygen impinged upon the melt through a lance. This means that a relatively small amount of gas is injected into the melt through the bottom blowing. If the bottom blowing gas is injected into the melt in an amount of more than 9/100 the rate of oxygen blown through a lance, the agitation takes place so vigorously that reduction in tapping yield is substantial due to much slopping of the melt. On the other hand, if the amount of the bottom blowing gas is less than 1/200 the top-blowing gas, the necessary agitation of the melt cannot be obtained.

In addition, the amount of the bottom-blowing gas may preferably be restricted on the basis of the amount of molten metal to be treated, independently from the blowing rate of pure oxygen through a lance. According to this embodiment, the amount of gas to be injected into the melt is precisely regulated or adjusted such that the uniform mixing time is 20 seconds or more.

The uniform mixing time means the time which is required to uniformly mix the molten steel and molten slag only by the bottom-blowing. The uniform mixing time is a factor introduced by K. Nakanishi et al ("Ironmaking and Steelmaking" (1975) 3, 193) and is defined as follows.

Uniform Mixing Time $\tau = 800 \times \dot{\varepsilon}^{-0.4}$ (sec.)

$$\dot{\varepsilon} = 28.5 \frac{Q}{W_g} \times T \times \log(1 + z/148) \text{ (Watt/ton)}$$

wherein

Q = gas flow rate (Nm^3/min)
W_g = amount of molten steel (ton)
T = bath temperature (°K)
Z = depth of the bath (cm)

In a preferred embodiment, the uniform mixing time is more than 30 seconds. If the amount of gas falls within the limitation defined above, then thorough agitation will be obtained. If the uniform mixing time is less than 20 seconds, the agitation between molten steel and molten slag occurs so vigorously that the reduction of iron oxide in the molten slag proceeds excessively, reducing the content of the iron oxide, which is effective for dephosphorization of the molten steel. Furthermore, if the uniform mixing time is less than 15 seconds, there is much leakage of the molten steel from the nozzles, resulting in less tapping yield of steel.

If the uniform mixing time is longer than 70 seconds, i.e. the amount of the bottom blowing gas is much reduced, no agitation is expected, and the blowing process is substantially the same as the conventional oxygen steel making process with top-blowing. This results in a remarkable increase in the total amount of iron in the molten slag, and a decrease in the tapping yield. Thus, it is desirable to adjust the uniform mixing time to 20—70 seconds.

It can be said on the basis of experiments that, for example, when the bath depth is 250 cm the uniform mixing time of 20 seconds corresponds to bottom blowing at a rate of 0.5 Nm^3/min per ton of molten steel, and uniform mixing time of 70 seconds to 0.02 Nm^3/min per ton of molten metal.

Noting the fact that oxygen gas is discharged primarily as carbon monoxide gas after the decarburizing operation in such oxygen top-blowing refining furnace, this invention, in one aspect, provides a steel refining process that utilizes said waste gas as the only source of the gas to be blown from below the melt bath to stir it. In so doing, the process supplies its own gas for stirring the molten steel.

This invention, therefore, also resides in a process for making steel in a basic oxygen furnace by the top-blowing of pure oxygen and the bottom-blowing of a gas mainly composed of carbon dioxide, characterized in that a waste gas discharge and collected from said furnace is combined with additional oxygen and/or steam, the mixture thereof is burned, and the resulting combustion gas mainly composed of carbon dioxide is used as at least a part of the bottom-blowing gas.

Since the combustion gas sometimes contains a relatively large amount of nitrogen gas, it is preferable to remove the nitrogen gas, or to collect carbon dioxide from the combustion gas and then the gas rich in carbon dioxide is used as the bottom-blowing gas. The removal of nitrogen gas from the combustion gas is preferably carried out when low-nitrogen steel is intended to produce.

For carrying out the process above, a steel making apparatus having a gas circulation system, has been provided, which comprises, in combination, a basic oxygen furnace permitting both top-blowing of oxygen and bottom-blowing of carbon dioxide-rich gas, a device for collecting the waste gas generated from the furnace, a device for burning said gas with oxygen and/or steam, an optional device for separating the combustion gas into carbon dioxide and nitrogen, and a piping system for supplying the molten steel in the furnace with carbon dioxide generated from said burner and separator.

This invention also resides in a method characterized in that the top-blowing oxygen is injected through a lance onto the molten metal at an outlet velocity of Mach 0.8—2.0, preferably Mach 0.8—1.5.

The oxygen top-blowing steelmaking process of this invention, in another aspect, resides in a method characterized in that a powder of a slag-forming agent (flux) comprising quick lime, limestone, fluorite, dolomite, iron ore or mixtures thereof is supplied together with a top-blowing oxygen jet, and at the same time, carbon dioxide is blown from below the molten steel throughout the period of oxygen top-blowing or even up to the time of the start of tapping, i.e. at least partly during the period of time from the beginning of blowing to the tapping of the melt.

In the case of using the conventional oxygen top-blowing converter, the oxygen jet may be supplied with a powder from a conventional oxygen top-blowing lance. However, the supply of a powder into a high-pressure oxygen piping inevitably results in a high equipment cost. Therefore, a separate path is provided for directing the powder on a carrier gas up to the tip of the oxygen blowing lance and for mixing the powder with an oxygen jet being delivered from the nozzle of the lance. By so doing, the defects mentioned above of the LD—AC process can be eliminated without abrasion of the Lavel-type oxygen blowing nozzle. More specifically, a three-sheathed lance (four coaxial tubes) used in one embodiment of this invention (see Figs. 6 and 7 referred to hereinafter) is one example of such method. The carrier gas for the flux powder is not specified, and a suitable gas can be selected

depending upon the composition and particle size of the flux, the inside diameter of the piping, the type and flow rate of the carrier gas or the type of the furnace used. But is is desired that the total amount of a given flux powder be supplied within about three quarters of the blowing period. This is in order to dissolve the flux within the period of refining operation and rapidly form a reactive slag for effective refining operation.

According to the process of this invention, a gas is blown from below the molten steel together with the supply of a flux through a lance, and the bottom blowing gas is preferably blown at a rate of 0.02 to 0.50 Nm^3/min per ton of the molten steel in case the bath depth is 250 cm. Within this range, less oxidation of iron and manganese takes place as the gas flow rate increases. Therefore, by choosing a suitable pattern for blowing the flux and for blowing the gas from below the melt bath depending upon the type of the steel to be produced, a steel of a desired final composition can be produced with high accuracy, in high yield and with great ease.

The features of this invention have been described hereinbefore in detail.

This invention is particularly applicable to produce carbon steel, such as rimmed steel, killed steel etc., and low-alloy steel. More particularly, this invention provides a satisfactory method of producing low-carbon steel, such as carbon steel containing less than 0.3% C.

Comparing the conventional process with this invention method, the following advantages of this invention are noted.

Since the oxidation of iron, manganese etc. is significantly inhibited, the yield of iron is markedly improved and the amount of ferro-alloys used may be decreased. In addition, since the temperature difference between the molten steel and the slag diminishes, the dephosphorizing is promoted. Another advantage of this invention is that the blowing gas, i.e. carbon dioxide, is abundant in a steel making plant and is available at low cost. This is an economical aspect of this invention. Thus, this invention has also a practical value in the light of the present day demand for saving energy and preventing the discharge of pollutants into the environment.

As hereinbefore mentioned, the method of this invention can easily be practiced in the usual steel making process by installing at least one nozzle in the conventional basic oxygen furnace. Of course, the application of this invention is not limited to the existing oxygen converters. As far as the combination of the top-blowing and the bottom-blowing is possible, this invention is applicable to any type of metal refining furnace.

Fig. 1 is an elevational side view diagrammatically showing the bottom-blowing BOF utilized in this invention,

Fig. 2 is a graph showing the blowing patterns of this invention,

Fig. 3 is a schematic diagram illustrating the arrangement of the steel making apparatus according to this invention,

Figs. 4 and 5 are graphs showing the effect of this invention,

Fig. 6 is a bottom view of the three-sheathed lance to be used in one embodiment of this invention, and

Fig. 7 is a longitudinal cross section of said lance taken on the line a-a of Fig. 6.

According to this invention, molten iron, iron scrap and other starting materials are charged into a bottom-blowing BOF, i.e. converter 1, as shown in Fig. 1. Two to ten concentric nozzles 2 are provided at the bottom of this oxygen converter. During operation of the converter pure oxygen is impinged onto the surface or into the molten metal 3 through a lance 4 while the bottom-blowing gas predominantly comprised of carbon dioxide is blown into the molten metal by way of the nozzles 2. The nozzles are arranged in two rows in this example. It is to be noted, however, that the structure, arrangement and number of the nozzle are not limited to particular ones.

In a preferred embodiment of this invention, a blow of gas predominantly comprised of carbon dioxide and supplied by way of conduits 5 is introduced into the molten metal 3 through concentric nozzles 2 provided in the bottom of said basic oxygen furnace at least partly during the period of time from the beginning of blowing to the tapping of the melt and the flow rate of the bottom blowing gas is less than 9/100 the rate of oxygen blown onto the melt through lance 4.

In one embodiment of this invention, the uniform mixing time is adjusted to 20 seconds or more.

Another embodiment of this invention is now described by reference to Fig. 3, an oxygen steel furnace 31 has an oxygen top-blowing lance 32 and a series of gas bottom-blowing nozzles 33. Oxygen gas is blown from the top-blowing lance 32 into the furnace 31 to perform decarburization and is discharged primarily as carbon monoxide gas. A gas primarily consisting of carbon dioxide is jetted from the bottom-blowing nozzles 33 into the furnace 31 where it is decomposed following the course $C + CO_2 \rightarrow 2CO$ and discharged from the furnace. These two supplies of carbon monoxide gas are caught in a hood 34 on top of the furnace 31. They contain less than 20 vol% of nitrogen gas since they entail atmosphere as they are being caught in the hood.

The gas caught in the hood 34 is first freed of dust through a dust collector 35 and transferred to a gas holder 36 where it is stored temporarily before proceeding to subsequent treatments. The gas in the holders 36 is mixed with oxygen and/or steam prior to entering into a burner 37. The gas in the holder 36 may be burnt with oxygen coming from an oxygen holder 41 for supplying oxygen to the oxygen top-blowing lance 32, and is optionally dehumidified before it is transferred to a carbon dioxide holder 39, or

after the burning, the gas may be denitrified in a CO_2/N_2 separator 38 to increase the CO_2 content before it is transferred to the carbon dioxide holder 39.

The carbon dioxide transferred to its holder 39 is supplied to the gas bottom-blowing nozzle 33 through the flow regulator 40. Alternatively, it may be combined with untreated gas from the gas holder 36 before it is supplied to the nozzle 33.

The gas jetted from the bottom-blowing nozzle 33 into the bath is again caught in the hood 34 together with the carbon monoxide resulting from decarburization. Thus, each supply of carbon monoxide gas and carbon dioxide gas keeps recycling through the path described above.

Another embodiment of this invention is now described by reference to Figs. 6 and 7. A 2-ton pure oxygen top-blowing converter is provided with two bottom nozzles (I.D. 8 mm) through which a gas is to be blown from below the melt bath. The oxygen top-blowing lance used is a three-sheathed lance (four coaxial tubes) 61 as shown in the bottom view and longitudinal cross section of Figs. 6 and 7, wherein the center of the disc 63 of its tip 62 is provided with a single nozzle opening 65, 10 mm in diameter serving as a passage 64 for the supply of a flux powder and said opening is surrounded by three nozzle openings 67 each 4.2 mm in diameter serving as a passage 66 for the supply of oxygen. This lance permits the powder to be blown against the surface of the melt 68 as it is mixed with oxygen being jetted from the three surrounding points.

This invention will be further described in conjunction with the working examples.

EXAMPLE 1

A conventional oxygen converter with the capacity of 250 tons was used to carry out this invention. Four nozzles 10 mm in diameter were installed at the bottom of the converter. Into this converter, as main starting materials, 215 tons of molten iron and 35 tons of scrap iron, and, as other starting material, 3 tons of quick lime were charged. The composition of the molten iron was, by weight percent, 4.63% C, 0.48% Si, 0.45% Mn, 0.123% P, 0.0018% S, 0.0038% N and the balance iron and indicental impurities. The temperature thereof was 1385°C.

The gas blowing from the top and from the bottom was carried out as in the following.

The top-blowing of oxygen was carried out at a flow rate of 40,000 Nm^3/hr in accordance with the flow pattern shown in Fig. 2. The bottom blowing was also carried out following the flow pattern shown in Fig. 2. As shown in Fig. 2, the bottom blowing was initiated at a flow rate of 50 Nm^3/hr and the rate was increased to 100 Nm^3/hr when the top-blowing of oxygen was initiated. At the end stage of the blowing, the rate of the bottom blowing was increased to 200 Nm^3/hr and was then reduced to 50 Nm^3/hr after the top-blowing was finished. The bottom blowing gas was an exhaust gas obtained from an oxygen converter and comprised, by weight percent, 18% CO, 63% CO_2, 16% N_2 and 3% H_2.

For the purpose of comparison, a conventional oxygen steel making process was also carried out using the same oxygen converter. The composition of the starting material charged into the converter and the manner of top-blowing were the same as in the above. In this case, however, the bottom blowing was not applied. The intended product steel was low-carbon rimmed steel. Table 1 below summarizes the final composition of the molten steel.

TABLE 1

	Composition (% by weight)					Tem. (°C)	T.Fe in slag (%)	Tapping yield (%)
	C	Mn	P	S	N			
This Invention	0.063	0.16	0.017	0.012	0.0025	1625	13.8	96.3
Con-tional	0.065	0.12	0.021	0.015	0.0011	1618	19.5	95.8

As is apparent from the data shown in Table 1 above, the product steel of the method of this invention has the composition falling within that of low-carbon rimmed steel and also shows a remarkably efficient dephosphorization and tapping yield.

EXAMPLE 2

In this example, Example 1 was repeated except that various kinds of gases were used as the bottom blowing gas.

As hereinbefore mentioned, the bottom blowing gas of this invention may be an exhaust gas discharged from an iron making plant, or a steel making plant. In this example, therefore, such kind of exhaust gas was used as the bottom blowing gas. Gas No. 1 was derived from an exhaust gas discharged from an oxygen converter and was made rich in carbon dioxide. Gas No. 2 was derived from an exhaust gas discharged from a hot stove and was made rich in carbon dioxide.

The final composition of the molten steel in each run is summarized in Table 2 below.

TABLE 2

Gas No.	Gas composition (% by volume)				
	CO_2	CO	N_2	H_2	O_2
1	95	0	5	0	0
2	52.6	0	43	3.2	1.2

TABLE 3

Gas No.	Final composition (% by weight)			T.Fe in slag (%)	Temp. (°C)
	C	Mn	N		
1	0.058	0.15	0.0019	14.2	1632
2	0.063	0.15	0.0085	14.5	1619

According to this invention, an exhaust gas discharged from the oxygen converter may be used as the bottom blowing gas. If the nitrogen content of the exhaust gas is below 50% by volume, the nitrogen content of the resulting steel product is acceptable. In addition, according to this invention, the agitation of the melt was effected thoroughly, resulting in sufficient degree of decarburization and dephosphorization to make the method of this invention practical.

EXAMPLE 3

The following starting materials were charged into an oxygen converter shown in Fig. 1. The capacity of the converter was 250 tons and the bath depth was 250 cm. Two concentric nozzle were provided at the bottom (the inner nozzle was 12.7 mm in inner diameter and 15.4 mm in outer diameter, the slit width was 1.15 mm, and the outer nozzle was 17.7 mm in inner diameter and 19.1 mm in outer diameter.

Molten iron: 220 tons

The [Mn] is about 0.40% and [p] is about 0.150% in molten iron.

Scrap iron: 30 tons

Other materials:

quick lime	9 tons
iron ore	4.5 tons
light dolomite	3.0 tons
fluorite	0.2 ton
converter slag	1.8 tons

According to the method of this invention, various kinds of bottom blowing gas were injected into the melt while top-blowing pure oxygen through a lance. The blowing conditions and the resulting uniform mixing time are summarized in the following Table 4.

TABLE 4

Run No.	top-blowing	bottom-blowing		B)/A)	bath temp. (°C)	uniform mixing time (second)	T.Fe in slag. (%)	final carbon content (%)	tapping yield (%)
	A) flow rate (Nm^3/min)	gas composition (by volume)	B) flow rate (Nm^3/min)						
1	600	Ar:CO_2=40:60	20 (32)	3.3/100	1600	33.7	11	0.05	96.2
2	600	CO:CO_2=40:60	7 (11.2)	1.2/100	1600	51.2	13	0.05	96.0
3	600	none	none	–	1600	–	20	0.05	95.5

Note:

In Runs 1 and 2, the carbon dioxide injected increases twice in volume in accordance with the following equation: $CO_2 + C = 2CO$. Thus, the flow rate of the bottom blowing gas in Runs 1 and 2 were, in fact, 32Nm^3/min and 11.2 Nm^3/min, respectively.

EXAMPLE 4

In this example, an oxygen top-blowing converter with the capacity of 2 tons was used. Two nozzles 6 mm in diameter were provided in the bottom of the converter.

Carbon dioxide gas was injected into the molten metal through the nozzles. The top-blowing oxygen was supplied through the straight type nozzles and Laver-type nozzles.

In one series of experiments, the flow rate of the bottom blowing carbon dioxide gas was varied. In another series of experiments, the outlet velocity of the top-blowing oxygen was varied.

Other experimental conditions were:

molten iron: 2000 kg, 1380°C,
4.20% C, 0.52% Si, 0.61% Mn,
0.121% P, 0.020% S

scrap: 360 kg

oxygen flow rate: 6 Nm^3/min

oxygen pressure before passing into the lance: 5 kg/mm^2

distance between the lance tip and the bath surface: 300 mm

carbon dioxide flow rate: 0.1—2.3 Nm^3/min. ton

oxygen jet velocity: Mach 0.3—2.3

blowing period: 18.6 minutes

Under these conditions, the tapping yield and the oxygen effect were determined. The results are summarised in Figs. 4 and 5. Fig. 4 shows the results obtained when the flow rate of carbon dioxide was varied as indicated with an outlet velocity of oxygen of Mach 1. Fig. 5 shows the results obtained when the outlet velocity of oxygen was varied as indicated at a carbon dioxide flow rate of 1 Nm^3/min. ton.

The data plotted in Figs. 4 and 5 are shown in comparison with those obtained in the conventional oxygen top-blowing process, and no bottom-blowing is employed.

From the results shown in Fig. 4 it is noted that improved tapping yield (shown by graph A) and oxygen effect (shown by graph B) in comparison with those of the conventional process were obtained when an flow rate of carbon dioxide of 0.3—2.0 Nm^3/min. ton was employed at an outlet velocity of oxygen of Mach 1. It is also noted from Fig. 5 that improved tapping yield (shown by graph A) and oxygen effect (shown by graph B) in comparison with those obtained in the conventional process were obtained when an outlet velocity of oxygen of Mach 0.8—2.0, preferably Mach 0.8—1.5 was employed at a carbon dioxide flow rate of 1 Nm^3/min. ton.

EXAMPLE 5

The steel making apparatus comprised a 250-ton oxygen top-blowing converter provided with four bottom-blowing nozzles and the gas circulation system comprising the components described above in conjunction with Fig. 3. The refining conditions were as follows: the molten iron consisted of 4.63% C, 0.51% Si, 0.43% Mn, 0.115% P, 0.023% S and the remainder Fe; the melt temperature was 1358°C, the hot metal ratio was 87%, and 3.5 tons of iron ore was charged together with auxiliary materials composed of 11 tons of quick lime and 8 tons of dolomite. The supply rate of top-blown oxygen was 40,000 Nm^3/hr. The waste gas recovered through the above circulation system was burnt, denitrified, and supplied at a flow rate of 1,500 Nm^3 hr as a bottom-blown gas that consisted of 98.5 vol% CO_2 and 1.5 vol% N_2. The refining pattern was adapted for the production of low-carbon rimmed steel: oxygen was blown in the same manner as in the conventional method whereas a constant flow of bottom-blown gas was supplied up to the time of start of tapping.

The results of the refining were: a waste gas consisting of 71.1 vol% CO, 15.2 vol% CO_2, 10.5 vol% N_2 and 3.2 vol% H_2O could be recovered from the furnace in a quantity of 108,000 Nm^3/hr. The steel obtained had a final analysis of 0.0058% C, 0.01% Si, 0.11% Mn, 0.018% P, 0.020% S, 0.0011% N and the remainder Fe, and its temperature was 1628°C. This indicates the fact that refining operations such as decarburization and denitrification were adequate for the making of the desired steel.

EXAMPLE 6

The converter equipped with such system was operated by four different methods: the process of this invention (I), the LD—AC process (II), the process wherein oxygen was blown from above and a gas was blown from below and a flux was supplied as a mass (III), and the conventional oxygen top-blowing

process (IV). In each case, the following conditions were employed, and the results shown in Table 5 below were obtained. Composition of molten iron: 4.3% C, 0.50% Si, 0.58% Mn, 0.125% P and 0.023% S.

Temperature: 1380°C

Charge: 2000 kg of molten iron and 370 kg of scrap

Flow rate of top-blown oxygen: 6 Nm^3/min. ton

Powder carrier gas: argon gas at 1 Nm^3/min

Bottom-blown gas: carbon dioxide gas at 1 Nm^3/min

Distance (h) between lance and molten metal surface: 300 mm

Blowing period: 17.3 min

TABLE 5

	Chemical analysis (%)					Tem. (°C)	Slopping	T.Fe in slag (%)	Yield (%)
	C	Si	Mn	P	S				
I	0.38	–	0.30	0.012	0.019	1680	no	6.3	+0.5
II	0.39	–	0.15	0.013	0.021	1685	much	21.8	–0.7
III	0.38	–	0.27	0.035	0.021	1680	no	6.5	+0.4
IV	0.41	–	0.14	0.044	0.025	1690	no	7.3	0

As is apparent from the foregoing, the method of this invention is very practical, since the existing oxygen converter may be utilized merely by installing a nozzle at the bottom or at the side wall of it. In addition, the gas to be used as the bottom blowing gas may be an exhaust gas obtained from the converter with or without further treatment of increasing the concentration of carbon dioxide. Thus, the method of this invention is easily applicable to the existing oxygen converter and will bring about practical advantages.

CLAIMS

1. A method of producing carbon steel and low-alloy steel in a basic oxygen furnace comprising preparing a molten metal suitable for producing the steel in said basic oxygen furnace, carrying out the top-blowing and bottom-blowing and then tapping the resulting molten steel, characterized in that a blow of the bottom-blowing gas predominantly comprised of carbon dioxide is introduced into the molten metal through at least one nozzle provided in the bottom or side wall of said basic oxygen furnace at least partly during the period of time from the beginning of blowing to the tapping of the melt, the flow rate of the bottom-blowing gas being 1/200—9/100 the rate of oxygen impinged upon the melt through a lance.

2. A method as defined in Claim 1 above, in which the nitrogen content in said bottom blowing gas is limited to not more than 20% by volume.

3. A method as defined in any one of Claims 1 or 2, in which the bottom-blowing gas contains a small amount of oxygen.

4. A method as defined in any one of Claims 1—3, in which the amount of the bottom-blowing gas is adjusted so that the uniform mixing time is longer than 20 seconds.

5. A method as defined in Claim 4, in which the uniform mixing time is 20—70 seconds.

6. A method as defined in any one of Claims 1—5, which further comprises collecting a waste gas discharged from said basic oxygen furnace, combining the waste gas with oxygen and/or steam, burning the mixture thereof and then recovering the resulting combustion gas to blow it into the molten metal as at least a portion of the bottom-blowing gas.

7. A method as defined in Claim 6, in which carbon dioxide is recovered from the combustion gas and is blown into the molten metal, as at least a portion of the bottom-blowing gas.

8. A method as defined in any one of Claims 1—7, in which the top-blowing gas is impinged onto the molten metal at an outlet velocity of Mach 0.8—2.0.

9. A method as defined in Claim 8, in which the top-blowing gas is impinged onto the molten metal at an outlet velocity of Mach 0.8—1.5.

10. A method as defined in any one of Claims 1—9, in which a powder of a slag-forming agent is introduced into the molten metal together with the top-blowing oxygen jet.

11. A method as defined in Claim 10, in which said slag-forming agent is at least one of quick lime, limestone, fluorite, dolomite, iron ore and mixtures thereof.

12. A steel making apparatus having a gas circulation system, which comprises, in combination, a furnace permitting both top-blowing of pure oxygen and bottom-blowing of a gas mainly composed of carbon dioxide, means for collecting the waste gas generated from the furnace, means mixing the waste gas with oxygen and/or steam, means for burning the mixture thereof, and means for passing the resulting combustion gas through a piping system to inject it into the molten metal within said furnace.

13. A steel making apparatus as defined in Claim 12, which further comprises a means for separating carbon dioxide from the combustion gas, the separated carbon dioxide being injected into the molten metal as at least a portion of the bottom-blowing gas.

14. A steel production method substantially as hereinbefore specifically described.

15. A steel making apparatus substantially as hereinbefore described and shown in the accompanying drawings.

16. Steel when produced by a method as claimed in any one of Claims 1 to 11 or 14 or in an apparatus as claimed in any one of Claims 12, 13 or 15.

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